Technical Protocol of the APMP Key Comparison APMP.AUV.V-K3.1

1. Task and Purpose of the Comparison

Since recent improvements at the APMP NMIs have extended the low-frequency vibration limit of calibration capabilities down to 0.1 Hz, the decision was taken to make a preparation of comparison during the meeting of APMP TCAUV in 2017. The task of the comparison is to compare measurements of linear vibration calibration within the frequency range from 0.1 Hz to 40 Hz. The results of this APMP comparison will, after approval by CCAUV, serve as evidence at low vibration frequency for the registration of 'calibration and measurement capabilities' (CMC) for NMIs in the framework of the CIPM MRA.

It is the task of the comparison to measure the complex sensitivity of one standard acceleration measuring chain or simply calling an accelerometer standard set (including a quartz-flexure servo-accelerometer of single-ended type and a signal conditioner) at different frequencies with acceleration amplitudes as specified in section 3. The voltage sensitivity is to be calculated as the ratio of the amplitude of the output voltage of the accelerometer standard set to the acceleration at its reference surface. The magnitude of the complex voltage sensitivity shall be given in millivolt per metres per second squared ($mV/(m/s^2)$) and the phase shift in degrees.

For the calibration of the accelerometer standard set, laser interferometry in compliance with method 1 or method 3 of the international standard ISO 16063-11:1999 has to be applied, in order to cover the entire frequency range.

The reported complex sensitivities and associated uncertainties will be used for the calculation of the 'degrees of equivalence' (DoE) between the participating NMI and to the key comparison reference value established for CCAUV.V-K3.

2. Pilot Laboratory

Pilot laboratory for this regional key comparison is

Precision and Dynamic Engineering Metrology Laboratory

Measurement Standards and Technology Division

Center for Measurement Standards (CMS), Industrial Technology Research Institute (ITRI)

Building 16, No. 321, Section 2, Kuang Fu Road, Hsinchu, 30011, Taiwan

This is the address for delivery of the circulating artefacts and the written and signed reports.

Contact Persons are

TU Tsung-Hsien	WANG Sheng-Han
Tel.:+886 3 574 3791	Tel.: +886 3 574 3719
e-mail:thtu@itri.org.tw	shwango@itri.org.tw
Fax:+886 572 6445	

Co-Pilot laboratory for this regional key comparison is

Vibration and Gravity Laboratory

Mechanics and Acoustics Metrology Division

National Institute of Metrology, P.R. China

BeiSanHuanDongLu 18, ChaoYang District, 100013 Beijing, P.R. China

Contact Person is

YANG Lifeng
Tel:+86 10 64524606
e-mail: yanglf@nim.ac.cn
Fax:+86 10 10 64218628

3. Device under Test and Measurement Conditions

For the calibration task of this key comparison, one quartz-flexure accelerometer set will be circulated between participating laboratories. The set includes a ‘single-ended’ (SE) servo accelerometer, namely a SA 704 (SN: to be decided), with a signal conditioner, namely MSA-I (SN: to be decided) and a power supply for the conditioner.

The complex voltage sensitivity of the accelerometer set shall be calibrated according to those procedures and conditions implemented by the laboratory in conformance with ISO 16063-11. The complex sensitivities reported shall be for the complete accelerometer set (or acceleration measuring chain), including all effects from the signal conditioner. The frequency range of the measurements is from 0.1 Hz to 40 Hz. Specifically, the laboratories are supposed to measure at the following frequencies (all values in Hz):

0.1, 0.125, 0.16, 0.2, 0.25, 0.315, 0.4, 0.5, 0.63, 0.8, 1, 1.25, 1.6, 2, 2.5, 3.15, 4, 5, 6.3, 8, 10, 12.5, 16, 20, 25, 31.5, 40.

Depending on the stroke limitation of the shaker used the NMI some frequencies can be considered optional as listed below.

0.1 to 0.4	0.5 to 20	25 to 40
optional	mandatory	optional

The measurement conditions should be kept according to the laboratory's standard conditions for calibration of customers’ accelerometers for claiming their calibration capabilities or CMC where applicable. This presumes that these conditions comply with those defined by the applicable ISO documentary standards [1, 2, 3], simultaneously.

Specific conditions for the measurements of this KC are:

- acceleration amplitudes: a range of 0.05 m/s^2 to 30 m/s^2 is recommended.

- ambient temperature and accelerometer temperature during the calibration:
  (23 ± 2) ℃ (actual values to be stated within tolerances of ± 0.3 ℃).
- relative humidity: max. 75 % RH.
- the input line voltage of the power supply for the signal conditioner is 220 V.

4. Circulation Type, Schedule and Transportation

The transducer set will be circulated between the participating laboratories considering a measurement period of two weeks provided for each participating laboratory and one week for the pilot laboratory.

At the beginning and the end of the circulation as well as between certain subsequent measurements of participating laboratories, the transducer set is measured by the pilot laboratory in order to check reference values and to monitor the stability of the transducer set.

The schedule is planned as follows:

Participant	Measurement	Transportation to next Participant
ITRI-CMS	2018/05/21 - 2018/05/27	2018/05/28 - 2018/06/04
NIM	2018/06/05 - 2018/07/08	2018/07/09 - 2018/07/15
NIMT	2018/07/16 - 2018/07/29	2018/07/30 - 2018/08/05
KRISS	2018/08/06 - 2018/08/19	2018/08/20 - 2018/08/26
NMISA	2018/08/27 - 2018/09/09	2018/09/10 - 2018/09/16
CSIR-NPLI	2018/09/17 - 2018/09/28	2018/09/29 - 2018/10/07
ITRI-CMS	2018/10/08 - 2018/10/12	

The cost of transportation to the next participating laboratory shall be covered by the participating laboratory. The transducer set has to be hand-carried with great caution. In case the transducer set gets damaged or lost during transportation, the participating laboratory responsible for the delivery should pay 6,000 € to the pilot laboratory.

5. Measurement and Analysis Instructions

The participating laboratories have to observe the following instructions:

- The motion of the quartz-flexure accelerometer shall be measured on the moving part of the horizontal vibration exciter, close to the accelerometer's mounting surface, since the mounting (reference) surface is usually not directly accessible.
- The mounting surface of the accelerometer and the moving part of the exciter must be slightly lubricated before mounting.
- The cable between accelerometer and signal conditioner should be taken from the set delivered to the laboratory.
- It is advised that the measurement results should be compiled from complete measurement

series carried out at different days under nominally the same conditions, except that the accelerometer is remounted and the cable re-attached. The standard deviation of the subsequent measurements should be included in the report.

- Participants should not perform any experiments other than comparison measurements stipulated in this protocol with the artifact.

6. Communication of the Results to Pilot Laboratory

Each participating laboratory shall submit one printed and signed calibration report for the accelerometer set to the pilot laboratory, including the following:

- a description of the calibration systems used for the comparison and the detailed information about the mounting of the accelerometer
- a description of the calibration methods used
- documented record of the ambient conditions during measurements
- the calibration results, including the relative expanded measurement uncertainty, and the applied coverage factor for each value.
- a detailed uncertainty budget for the system covering all components of measurement uncertainty (calculated according to GUM [4, 5]). Including, among others, information on the type of uncertainty evaluation (A or B), assumed probability distribution and repeatability component.

In addition, the use of the electronic spreadsheets that will be provided by the pilot laboratory for reporting is mandatory. The consistency between the results in electronic form and in the printed and signed calibration report is responsibility of the participating laboratory. The data submitted in the electronic spreadsheet shall be deemed the official results submitted for the comparison.

The results have to be submitted to the pilot laboratory within six weeks after the measurements have been completed.

The pilot laboratory will submit its set of results to the executive secretary of CCAUV in advance to start the circulation for measurements by the other participating laboratories.

7. Remarks on post processing

Presuming consistency of the results, the degrees of equivalence will be calculated according to the established methods agreed upon already for CCAUV.V-K1. This regional key comparison is to be linked to the CIPM key comparison CCAUV.V-K3. The DOEs will be determined in reference to the key comparison reference value (KCRV) calculated for CCAUV.V-K3.

8. References

[1] ISO 16063-1:1998 ‘Methods for the calibration of vibration and shock transducers - Part 1: Basic concepts

[2] ISO 16063-11:1999 ‘Methods for the calibration of vibration and shock transducers - Part 11: Primary vibration calibration by laser interferometry’

[3] ISO/IEC 17025:2005 ‘General requirements for the competence of testing and calibration laboratories’

[4] ISO/IEC Guide 98-3:2008 ‘Uncertainty of measurement -- Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)

[5] ISO/IEC Guide 98-3:2008/Supplement 1:2008 ‘Propagation of distributions using a Monte Carlo method’